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Application and design of fuzzy intelligent evaluation software for sand production and steam channeling prediction of steam injection well

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Abstract

Fuzzy intelligent evaluation software is designed to predict situation of sand production and steam channeling for steam injection well, which can improve the development effect of heavy oil reservoir. Based on expert knowledge, the software transfers the qualitative knowledge into quantitative index by the use of fuzzy evaluation and grey relational analysis. Combined with actual data of oil field as sample set, the software establishes an intelligent optimization analysis model through neural network and numerical analysis methods. Through multi-model regression analysis, optimum model and its parameters can be chosen to predict the production effect. This software adopts three-tier model, with which the structure has the following advantages: reasonable design, reliable performance, convenient operation, high portability and good expansibility. According to the calculated results of actual data of oil field, the software can predict sand production and steam channeling more effectively, and guide further formulation and improvement of development program.

Keywords: heavy oil ;steam injection well; sand production; steam channeling; evaluation and prediction; software design

1. Introduction

Heavy oil reservoir is the most important part of oil geological reserves in China. Thermal recovery by steam injection is the most effective way of heavy oil production. However, there are many problems in thermal recovery by steam injection to heavy oil reservoir [1]. First of all, the steam channeling phenomena of oil wells are serious, which may result in a series of problems. These problems seriously affect the normal oil production and the whole development effect of oil field. Second, steam with high

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temperature and high pressure directly undermines oil stratum taking clay as main cement. Sand production also seriously impacts oil well production. Domestic technologies pay much attention to the solutions of steam channeling and sand production and the choices of engineering methods. Those phenomena are irreversible. Once it generates, nothing can make it possible for actual production loss to be made up no matter what subsequent means will be adopted. Therefore, if it is possible to forecast the occurrence time of sand production or steam channeling, prepare for prevention and control methods, formulate scientific development plan and decrease the tendency of sand production and steam channeling occurrence, the oil reservoir will be protected, and the development effect can be improved. According to the above ideas, fuzzy intelligent evaluation software is designed [2, 3]. On one hand, based on the knowledge and experience of experts and technicists, the system transforms the qualitative knowledge into quantitative indexes by the use of fuzzy evaluation and grey relational analysis [4, 5]; On the other hand, combined with actual data of oil field as sample set, the system establishes intelligent optimization analysis model through neural network and the numerical analysis methods [6, 7]. And then with the quantitative expert knowledge as restricted parameters and actual data as initial sample, different models are screened out to study and calculate by using intelligent optimization analysis model. According to the study conclusions, fuzzy intelligent evaluation model can be built under the current conditions. Because the experience and actual data are comprehensively taken into considered, the model can predict sand production and steam channeling more effectively.

2. Fuzzy intelligent evaluation software

2.1. Software design idea

Fuzzy intelligent evaluation software (FIES) is software based on expert knowledge, field data and numerical calculation model, which uses methods of fuzzy evaluation, grey relational analysis and neural network to analyze, evaluate and predict sand production and steam channeling in heavy oil reservoir. FIES achieves corresponding expert knowledge according to the actual problems, quantifies expert knowledge through fuzzy evaluation method, and then establishes expert knowledge base. Grey relational analysis is used to analyze data features and set up sample database by getting further data. Combined with oil seepage characteristics, database with different seepage mathematical models is set up. On the basis of features of input data, corresponding data obtained from expert knowledge base and sample database are used as matching parameters to calculate and analyze different seepage mathematical models through neural network method. The optimization computation model and parameters are selected and applied to the prediction and analysis to actual data. According to the calculated results and expert knowledge, some suggestions are propounded to adjust the actual production plan.

2.2. Software structure and implement

FIES system structure is mainly composed of three parts: user level, program level and data level.

User level is the interface between FIES and all kinds of clients (system user, management user and ordinary user), which is made up of Chinese windows interface supported by mouse and keyboard and operated by the interactive way. User level includes data input module, function selection and operation module, data and graphics output module. Data input module is responsible for the input of expert knowledge, sample data and calculation data. Function selection and operation module is in charge of the switching among all sorts of functions. Data and graphics output module takes charge of the output of all kinds of data and charts to graphic interface and file system.

Program level of FIES is a module based on input data and data stored in database and different calculation models, which takes advantages of neural network method for data calculation, analysis and evaluation. This level is mainly consisted of data processing system and intelligent analysis calculation model. Processing system is responsible for expert knowledge's quantitative evaluation, analysis of

sample data, and data transmission to database management system. Intelligent analysis and calculation model is the core of the FIES. Based on the initial fuzzy information and fuzzy knowledge from fuzzy knowledge base, the model can duce the acceptable fuzzy conclusions in accordance with certain fuzzy reasoning strategy.

Data level is a place where FIES directly interact with database through database management system and also is the only place where database is allowed to access. This level is mainly composed of database management system and different databases. Database management system is responsible for the uniform management and control to database, in order to ensure the security and integrity of database. Knowledge base is mainly used to storage quantitative expert knowledge and conclusions derived from expert analysis. Sample base contains all kinds of dynamic and static data, and conclusions reasoned from FIES system. Model base is mainly applied to save various calculation models.

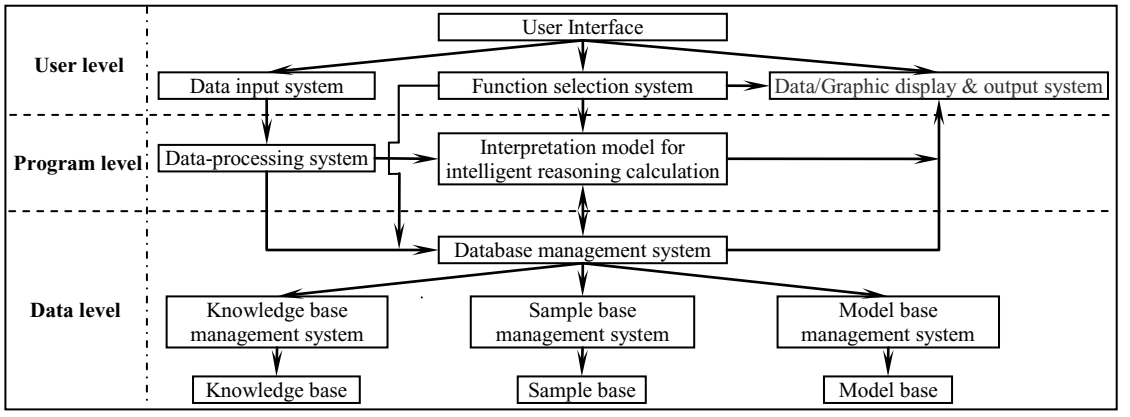

Fig. 1. Structure diagram of FIES

FIES adopts standard three-tier model. The visit relationships among all levels are as following: user level can only visit program level in one-way, while is invisible to data calculation and storage. Program level can only visit data level in one-way, in charge of information transition and data calculation and analysis. According to the orders of program level, data level which is used for calculation and output not only storages data and models of user level and program level in database, but also feeds them back to user level and program level.

2.3. Software functions and characteristics

FIES primarily contains two functions: one is the evaluation to development effects of steam injection well in heavy oil reservoirs. Combined with the production wells, experts experience and calculated results of models, further adjustment plan for development is proposed. The other is the prediction of sand production and steam channeling in new wells though regression analysis to available data, which is based on various calculation models and parameters. According to the forecast results and expert experience, development projects for new wells are made.

FIES is constituted by three-tier model, and each level is relatively independent, high fault-tolerance, good expansibility. Using muti-model regress to evaluate and predict the models and parameters, the results will highly coincide with the actual production. FIES quantifies the expert knowledge to realize human-machine interaction conveniently. At the same time, inference model is separate from knowledge base. The system operating capacity can be improved and enhanced by constantly extending and completing knowledge base, which will highly enhance the flexibility of system. The database is relatively independent, which makes data transplanted conveniently and also increases data availability.

3. Field application

Henan oilfield is located in central China. Since investment and development, due to repeatedly cyclic steam stimulation with high strength, sand production and steam channeling phenomena are serious. In order to improve the whole development effect of oilfield, FIES is used to analyze actual well conditions, which provides guidance for the further formulation and improvement of development program. Through analyzing the field data of 568 wells achieved by FIES, the preliminary influencing factors for sand production and steam channeling wells includes both geological and development factors. Thus, FIES can automatically screen and evaluate these influence factors, the results of which are as follows:

Table 1. Factor screening results

First level	Second level
Geographical factor	Uniformity coefficient; Formation sensitivity; Heterogeneity coefficient ; Sorting coefficient; Shale content; Median grain diameter; Consolidation degree; Rock wettability; Average porosity
Reservoir factor	Reservoir depth, temperature and pressure; Reservoir thickness; Asphaltenes content; Crude oil viscosity; Mean permeability; Permeability ratio; Anisotropy coefficient; High permeability layer thickness; Oil saturation
Well factor	Borehole size; Well completion method; Completion segment length; Perforation thickness; Drainage radius; Contamination degree
Production factor	Gas injection rate; Average injection pressure; Producing pressure drop; Average cyclic steam injection volume Average cyclic liquid-producing capacity; Average cyclic oil production; Cumulative oil output; Cumulative water output; Cumulative steam injection

Through analyzing and calculating the above data, FIES can be used for iterative computation by automatically selected optimum model, as shown in Fig. 2.

Through predictive analysis of selected optimum model to data of 142 wells, the results are shown in Table 2. Prediction results show that accuracy can exceed 90% and the biggest relative error is only 24.4%, which fulfils the actual project requirements.

Table 2. Prediction results

	Fitting rate	Maximum relative error
Sand production well	91.0%	24.4%
Steam channeling well	92.8%	17.8%
System	92.0%	24.4%

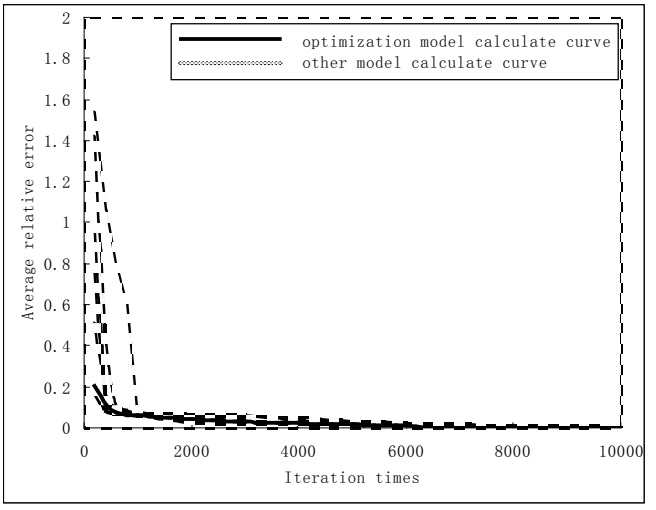

Fig. 2. Calculation curves of the model

4. Conclusions and discussions

Combined with the actual production data, FIES is used to quantify expert knowledge to construct knowledge base. Through multi-model calculation, optimum model and its parameters can be chosen to establish the mathematical model on the basis of actual production characteristics. For practical production wells, as long as the basis data are input, FIES can judgment the cycle and possibility of sand production and steam channeling correctly, and give advices for making and revising production plan.

Restricted by neural network system theory, FIES needs a mass of actual data as a sample data for fitting to obtain more accurate conclusions. Besides, experts with rich actual production experience conduct knowledge judgment according to the characteristics in actual production stage. And the knowledge base needs to be updated constantly.

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